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EXECUTIVE SUMMARY

With increasing customer expectations and limited funding, VDOT must ensure that the most cost-effective, smooth, and long-lasting pavements are constructed on Virginia's highways. With the volume of traffic using Virginia's highways, the public will no longer tolerate excessive work-zone disruptions because of emergency or unplanned maintenance on a roadway. Additionally, VDOT cannot afford to rehabilitate these pavements prematurely. Both the public and VDOT want VDOT to "Get In, Get Out, and Stay Out." To fulfill this expectation, VDOT is designing pavements using new approaches and enhanced state-of-the-art materials such as SUPERPAVE® asphalt, high performance concrete and analytical tools like HYPERPAVE.

In addition to new pavement design methods and materials, VDOT is incorporating a revised life cycle cost analysis (LCCA) procedure into the process of selecting pavement type. This analysis incorporates proven national methodologies (ACPA, FHWA Demo 115, Asphalt Institute) customized to Virginia's unique circumstances. With this new approach, VDOT looks beyond initial construction costs by considering the future maintenance and rehabilitation needs associated with a particular type of pavement. This approach, then, improves the decision-making process by enabling the selection of the most cost-effective type of pavement based on an estimation of *costs incurred* throughout a suitable analysis period, or "life cycle." For the LCCA procedure, a 50-year analysis period is considered sufficiently long to capture the maintenance and rehabilitation costs that span at least one full series of treatment activities. A review of the age and condition of many of Virginia's high-volume roadways, particularly interstate facilities, reveals that pavements constructed 25 to 40 years ago are now in need of major rehabilitation.

This document provides the framework for future enhancements to the LCCA process as we refine real maintenance cost and performance data based on actual experience. Anticipated future improvements to VDOT's LCCA approach include 1) the application of probabilistic concepts to account for the variability of input factors (unit costs, activity timing, etc.); and 2) the integration of user costs associated with work zone delays. The procedure herein was derived largely from the Federal Highway Administration Technical Bulletin, *Life Cycle Cost Analysis in Pavement Design*[1]. Geared toward state highway agency personnel responsible for designing highway pavements, the bulletin provides technical guidance and recommendations on "good practice" in conducting LCCA in pavement design. It was authored by representatives of various state transportation departments, the Federal Highway Administration (FHWA), the National Asphalt Pavement Association, and the American Concrete Pavement Association. References to applicable sections of the Technical Bulletin are made throughout this LCCA document. On subjects not specifically covered by the FHWA Technical Bulletin, VDOT's LCCA Guidelines draw upon the experience and expertise of its own workforce, particularly in areas related to pavement performance prediction and maintenance effectiveness. Where records are available, historic performance data were used to support planned maintenance/rehabilitation intervals for certain activities.

LCCA will enhance VDOT's ability to make sound engineering and cost-effective economic decisions pertaining to the construction/reconstruction of Virginia's major highways. However, it is important to remember that the LCCA process is based on the premise that the pavements are properly designed and will be reasonably maintained, that the quality of the construction and materials is consistently good, and that the pavement is not subject to adverse or unforeseen site conditions.

I. INTRODUCTION

A major factor in selecting the type of pavement for use on new construction and major rehabilitation projects is cost. In many cases, the initial construction cost is the main consideration. Although a particular pavement type may have a low initial cost, the future maintenance and rehabilitation costs may be exorbitant and, therefore, must be considered in a fair and objective decision-making process. In order to account for the initial and future costs associated with the construction and maintenance of roadway infrastructure, a life cycle cost analysis (LCCA) should be performed.

Purpose

The purpose of this document is to provide technical guidance to VDOT engineers involved in selecting a pavement type for major construction and rehabilitation projects. This document describes LCCA, the history of LCCA in VDOT, and projects requiring LCCA.

What Is LCCA?

LCCA is an economic method to compare alternatives that satisfy a need in order to determine the lowest cost alternative. According to Chapter 3 of the *AASHTO Guide for Design of Pavement Structures*[2], life cycle costs "refer to all costs which are involved in the provision of a pavement during its complete life cycle." These costs borne by the agency include the costs associated with initial construction and future maintenance and rehabilitation. Additionally, costs are borne by the traveling public and overall economy in terms of user delay. The life cycle starts when the project is initiated and opened to traffic and ends when the initial pavement structure is no longer serviceable and reconstruction is necessary.

History of LCCA in VDOT

VDOT has used LCCA to evaluate and select pavement types on new Interstate and Primary Route projects for many years. Past LCCAs for pavements considered a 24-foot surface width and dealt with the cost for a lane mile. A 30-year analysis period was used, and only continuously reinforced concrete, jointed concrete, and flexible pavements were considered.

LCCA Projects

LCCA may not be necessary on all projects largely because of the nature and location of a particular project. For most widening projects, for example, LCCA may not be necessary. In this case, because of visual and construction considerations, the new pavement is selected and designed to be similar to the adjacent pavements. This approach is consistent with design recommendations found in Appendix B of the *AASHTO Pavement Design Guide*[2]. For intersection improvement projects, the new pavement may be selected and designed based on local experience and construction issues. For most short projects (less than one mile), the new pavement will be similar to the adjacent pavements. In urban areas where numerous utilities are located under the pavement or cross under the pavement, a flexible pavement is typically selected. Flexible pavement can be removed and patched easier if utilities must be repaired, replaced, or installed. If utilities are not a concern, then either pavement may be feasible and the engineer should consider performing LCCA to assist in selecting the final structure.

LCCA should be used on large-scale construction and rehabilitation projects. Many of these projects are located on interstates and high-volume primary or secondary routes. For projects on routes like these, LCCA should be part of a large corridor improvement plan where practical.

Components of This Document

To aid the engineer in performing LCCA, this document has six major sections in addition to the Introduction. Section II describes the basic economic analysis components; Section III describes the cost factors included in LCCA; Section IV outlines the overview of LCCA pavement options; Sections V through XI provide information on each pavement option; Section XII provides unit costs and measures for each pavement-related activity; and Section XIII discusses the interpretation of results.

II. ECONOMIC ANALYSIS COMPONENTS

Analysis Period

To maintain consistency with the FHWA Technical Bulletin, *Life Cycle Cost Analysis in Pavement Design*[1], LCCA periods should be sufficiently long to reflect long-term differences associated with reasonable maintenance strategies. The analysis period should generally be longer than the pavement design period. As a rule of thumb, the analysis period should be long enough to incorporate at least one complete cycle of rehabilitation activity. The FHWA's September 1996 Final LCCA Policy Statement[3] recommends an analysis period of at least 35 years for all pavement projects, including new or total reconstruction projects and rehabilitation, restoration, and resurfacing projects (*Life Cycle Cost Analysis in Pavement Design*, FHWA, March 1998, p. 11). For VDOT's revised LCCA procedure, a 50-year analysis period was selected. This period is sufficiently long to reflect the service lives of several rehabilitation activities.

Discount Rate

In order to account for the cost related to future activities, the time value of money must be considered. In LCCA, the discount rate is used. The *discount rate* is defined as the difference between interest and inflation rates. Historically, this value has ranged from 2% to 5%; for LCCA purposes, a value of 4% will be used. This value is consistent with the values recommended in the FHWA Interim Technical Bulletin[1] and other economic research performed by VDOT[4]. The discount rate accounts not only for the increased cost associated with performing an activity in the future but also for the economic benefit the agency would receive if those funds were instead invested in an interest-bearing account.

Evaluation Methods

Numerous economic analysis methods can be used to evaluate pavement alternatives. The two most common are the present worth (PW) method and the equivalent uniform annual cost (EUAC) method.

The EUAC method describes the average cost an agency will pay per year over the analysis period. All costs including initial construction and future maintenance are distributed evenly. Although this dollar value may not seem realistic in years when little pavement action is required, it can be used to evaluate and compare alternatives.

The PW method reports initial and future pavement costs as a lump sum amount in today's dollar value. For activities that occur in the initial year of the analysis period, the PW cost is the same as the actual cost, i.e., no adjustment for inflation and interest. For future maintenance and rehabilitation activities, the PW cost is less than the actual cost (based on today's unit prices) since total costs are discounted. Please note that for two identical actions that occur 30 years apart, the later action will cost much less. This is because of the number of years that are discounted. The PW method is the more widely used approach for pavement LCCA. It gives an indication of how much a pavement alternative will cost over the analysis period and can be used to clearly compare alternatives for lowest cost.

Sensitivity Analysis

As with any analysis, it is important to understand what variables make the largest difference in the final results. For pavement design, the pavement subgrade strength and traffic loading have the largest impact on the design outcome. For LCCA, multiple variables can affect the final PW or EUAC for a pavement alternative. For example, the unit cost of a material alone can be significant enough to cause a particular alternative go from the lowest PW to the highest. Therefore, the engineer must ensure that the unit costs used are reasonable; likewise, it is important to understand how sensitive the cost of an alternative is to the input assumptions. This is accomplished by performing a limited sensitivity analysis whereby various combinations of inputs are selected to qualify their effect on the analysis results. Other factors that can greatly influence the LCCA results are discount rate, analysis period, and timing of activities.

III. COST FACTORS

Numerous costs are included in LCCA for pavements, ranging from initial costs associated with new construction to future maintenance costs associated with patching, sealing, and other activities.

Initial Costs

To conduct an LCCA for comparing pavement alternatives, the initial cost is a major percentage of the PW or EUAC over the analysis period. The initial cost is determined at Year 0 of the analysis period.

Although numerous activities are performed during the construction, reconstruction, or major rehabilitation of a pavement, only those activities that are specific to a pavement alternative should be included in the initial costs. By focusing on those activities, the engineer can concentrate on estimating the quantities and costs related to those activities. Actions dependent on pavement type include, but are not limited to the following:

- milling
- pavement removal
- asphalt concrete paving
- portland cement concrete paving
- fracturing portland cement concrete slabs.

Rehabilitation Costs

For all pavement options, the initial pavement life is designed to support traffic for 30 years. At the end of the 30-year period, the pavement must be rehabilitated. For flexible pavements, this rehabilitation includes removing AC surface and intermediate materials and replacing with new AC material. For rigid pavements, concrete pavement restoration (CPR) is conducted and an AC overlay may be placed. Rehabilitation activities may include the following:

- milling
- AC paving
- PCC and AC patching
- joint cleaning.

Structural/Functional Improvement Costs

Structural/functional improvement activities are performed during the life of a pavement in order to maintain a smooth, safe, durable pavement surface. Structural/functional improvements are designed to last 10 years. Typical improvement activities include the following:

- milling
- AC and PCC patching
- AC paving
- PCC grinding
- joint cleaning and sealing

Maintenance Costs

All pavement types require preventive and corrective maintenance during their service life. The timing and extent of these activities vary from year to year. Routine reactive type maintenance cost data are normally not available except on a very general, area wide type cost per lane mile. Fortunately, routine reactive type maintenance costs are generally not very high due to the relatively high performance levels maintained on major highway facilities. Further, state highway agencies that do report routine reactive maintenance costs note little difference between most alternative pavement strategies. When discounted to the present, small reactive maintenance cost differences have negligible effect on PW and can generally be ignored.[1] Therefore, they are not included in this LCCA procedure.

Salvage Value

At the end of the LCCA period, the pavement structure may be defined as having some remaining value to the managing agency, known as the salvage value. In many cases, a structural/functional improvement performed near the end of the analysis period retains some value in the form of useful life that extends beyond the end of the analysis period. The FHWA Interim Technical Bulletin[1] recognizes that a pavement's serviceable life represents a more significant component of salvage value than does its residual value as recycled material. In fact, the Bulletin states that the differential residual value between pavement design strategies is generally not very large, and when discounted over 35 years or more, tends to have little impact on LCCA results. For this reason, the VDOT LCCA procedure follows the recommendation of the Bulletin for Serviceable Life. This is defined as the remaining service life in a pavement alternative at the end of the analysis period. The following equation is used to define salvage value:

Salvage value = Structural/functional improvement cost at Year X * Percentage of remaining life at year 50

This approach is consistent with other state highway agencies such as the Utah DOT[5]. Even with this approach, the salvage value is negligible when discounted back 50 years.

IV. OVERVIEW OF LCCA PAVEMENT OPTIONS

In order to conduct a LCCA, different pavement options must be identified and compared for a project. The number and type of viable pavement options depend on the project's characteristics. After an examination of the pavement structures (flexible, rigid, and composite) that exist on Virginia's interstates and high-volume primary routes, seven pavement options were created. The following table identifies these pavement options:

Construction/Major Rehabilitation Pavement Options
Asphalt Concrete Construction/Reconstruction
Rehab of Rigid Pavement with AC Overlay
Rehab of Rigid Pavement with Unbonded Jointed Concrete Overlay
Jointed Plain Concrete Construction/Reconstruction with Tied PCC Shoulders
Jointed Plain Concrete Construction/Reconstruction with Wide Lane and AC Shoulders
Continuously Reinforced Concrete Pavement Construction/ Reconstruction with Tied PCC Shoulders
Continuously Reinforced Concrete Pavement Construction/ Reconstruction with Wide Lane and AC Shoulders

The pavement options, criteria and suppositions in the table were made to accommodate the consistent application of LCCA across the state. Without these guidelines, an infinite number of pavement options could be developed. For some pavement options, specific criteria and suppositions were made. The general criteria and suppositions made were:

1. No reconstruction is planned during the analysis period beyond the original rehabilitation/reconstruction.
2. Flexible pavements remain flexible throughout the analysis period, i.e., no white-topping.
3. Rigid pavements are overlaid with AC during the analysis period. No unbonded or bonded concrete overlays are programmed.
4. Subsurface drainage systems are independent of pavement type. If a site needs drainage, then all options call for drainage. Therefore, this cost is treated as fixed regardless of pavement type.
5. Full-depth shoulders are designed to carry potential future traffic.
6. The timing of functional improvements and major rehabilitation is fixed.
7. The activities associated with new construction, reconstruction, major rehabilitation, and functional improvements are a function of the project. The activities included in LCCA must be determined by the engineer and supported by documentation.

V. ASPHALT PAVEMENT CONSTRUCTION/RECONSTRUCTION

For most projects, asphalt pavement construction or reconstruction is a viable option. Asphalt pavement can be constructed on a new alignment or an existing alignment. For existing alignments, the in-situ pavement is removed completely.

As with all pavement options, several criteria were established and assumptions made:

1. The initial pavement design life is 30 years. Because of functional mill and replace at Year 12 and structural mill and replace at Year 22, major rehabilitation is not scheduled until Year 32.
2. For the structural rehabilitation at Year 32, the pavement surface life is 12 years. The pavement is considered "new" and to have a performance similar to new construction.
3. Structural/functional mill and replace is a fixed activity at Years 12, 22, and 44 in order to provide 10 additional years of life to the pavement surface and structure. The 10-year period is the average life for an AC surface based on data in VDOT's pavement management database.
4. For structural adequacy, the pavement overlay design life at Year 32 is 20 years. Pavement activities and required structures must be determined by the engineer (e.g., thickness of AC base, intermediate and surface layers,).
5. Patching of AC pavements is based on area of pavement surface.
6. Milling to a depth of 2 inches is performed to remove the 1.5-inch wearing course and a portion of the underlying layer to minimize scabbing.
7. Preventive maintenance activities considered in the analysis include surface treatments (e.g., BSTs, thin overlays, slurrys, microsurfacing), crack sealing, and patching. Preventative maintenance is only specified in the analysis for the shoulders if a functional or structural improvement is performed on the mainline pavement. No preventative maintenance is programmed for the mainline pavement as part of the LCCA.

Pavement Activities Table

Year 0 – New Construction/Reconstruction	**Year 12 – Functional Mill and Replace**
Mainline AC Surface Material AC Intermediate Material AC Base Material Stabilized Drainage Layer CTA or DGA Subbase Shoulders AC Surface Material	Mainline Pre-overlay repair - Patch – 1% Mill - 2 Inches Replace with AC Wearing Course - 2 Inches Shoulders Surface Treatment

Year 0 – New Construction/Reconstruction	**Year 12 – Functional Mill and Replace**
AC Intermediate Material AC Base Material Stabilized Drainage Layer CTA or DGA Subbase	

Year 22 – Structural Mill and Replace	**Year 32 – Major Rehabilitation**
Mainline Pre-overlay Repair - Patch – 1% Mill - 2 Inches Replace with AC Intermediate Materials – 2 Inches Overlay with AC Wearing Course – 1.5 Inches Shoulders Overlay with AC Wearing Course – 1.5 Inches	Mainline Pre-overlay Repair - Patch – 5% Deep Mill (All Surface and Intermediate Layers) Replace with AC Base Material AC Intermediate Material AC Wearing Course Shoulders Overlay with AC Wearing Course

Year 44 – Functional Mill and Replace	**Year 50 – Salvage Value**
Mainline Pre-overlay repair - Patch – 1% Mill - 2 Inches Replace with AC Wearing Course - 2 Inches Shoulders Surface Treatment	Salvage Value = [AC Overlay Cost at Year 44] – [AC Overlay Cost at Year 44 * (4-yr Remaining Service Life/10-yr Design Life)]

VI. REHAB OF RIGID PAVEMENT WITH AC OVERLAY

One pavement option for rehabilitating existing rigid pavement is fracturing and overlaying with AC. Fracturing techniques includes break and seat, crack and seat, and rubblization. The type of fracturing performed is based on the existing rigid pavement type, e.g., jointed plain, jointed reinforced, or continuously reinforced concrete. Once the pavement has been fractured and overlaid, it is considered a flexible pavement structure

As with all pavement options, several criteria were established and assumptions made:

1. The initial pavement design life is 30 years for fractured pavement areas and areas of pavement reconstruction. Because of the anticipated service lives resulting from the structural mill and replace at Year 12 and functional mill and replace at Year 22, major rehabilitation is not scheduled until Year 32.
2. For the structural rehabilitation at Year 32, the pavement surface life is 12 years. The pavement is considered "new" and to have a performance similar to major rehabilitation at Year 0.
3. Structural/functional mill and replace is a fixed activity at Years 12, 22, and 44 in order to provide 10 additional years of life to the pavement surface and structure. The 10-year period was determined to be the average life for an AC surface based on historic performance data in VDOT's pavement management database.
4. For pavement structural adequacy, the pavement overlay design life at Year 32 is 20 years. Pavement activities and required structures must be determined by the engineer (e.g., thickness of AC base, intermediate and surface layers).
5. The full-depth patching percentage for AC pavements is based on pavement surface area.
6. Milling to a depth of 2 inches is performed to remove the 1.5-inch wearing course and a portion of underlying layer to minimize scabbing.
7. Preventive maintenance activities considered in the analysis include surface treatments (e.g., BSTs, thin overlays, slurrys, microsurfacing), crack sealing, and patching. Preventative maintenance is only specified in the analysis for the shoulders if a functional or structural improvement is performed on the mainline pavement. No preventative maintenance is programmed for the mainline pavement as part of the LCCA.

Pavement Activities Table

Year 0 – PCC Overlaid with AC	**Year 12 – Functional Mill and Replace**
Mainline Fracture Existing PCC AC Surface Material AC Intermediate Material AC Base Material Stabilized Drainage Layer Shoulders (If Requires Reconstruction) Shoulder Removal AC Surface Material AC Intermediate Material AC Base Material Stabilized Drainage Layer CTA or DGA Subbase Soil Stabilization Shoulders (If Existing PCC) Fracture Existing PCC AC Surface Material AC Intermediate Material AC Base Material Stabilized Drainage Layer	Mainline Pre-overlay repair - Patch – 1% Mill - 2 Inches Replace with AC Wearing Course - 2 Inches Shoulders Surface Treatment

Year 22 – Structural Mill and Replace	**Year 32 – Major Rehabilitation**
Mainline Pre-overlay Repair - Patch – 1% Mill - 2 Inches Replace with AC Intermediate Materials – 2 Inches Overlay with AC Wearing Course – 1.5 Inches Shoulders Overlay with AC Wearing Course – 1.5 Inches	Mainline Pre-overlay Repair - Patch – 5% Deep Mill (All Surface and Intermediate Layers) Replace with AC Base Material AC Intermediate Material AC Wearing Course Shoulders Overlay with AC Wearing Course to match new profile

Year 44 – Functional Mill and Replace	**Year 50 – Salvage Value**
Mainline Pre-overlay repair - Patch – 5% Mill - 2 Inches Replace with AC Wearing Course - 2 Inches Shoulders Surface Treatment	Salvage Value = [AC Overlay Cost at Year 44] – [AC Overlay Cost at Year 44 * (4-yr Remaining Service Life/10-yr Design Life)]

VII. REHAB OF RIGID PAVEMENT WITH UNBONDED JOINTED CONCRETE OVERLAY

A rehabilitation option for existing rigid pavement is to place an unbonded jointed plain concrete pavement overlay. For this rehabilitation option, minimal repair is made to the existing rigid pavement, a thin AC bond-breaking layer is placed, and then a concrete pavement is placed. This pavement structure is considered rigid.

As with all pavement options, several criteria were established and assumptions made;

1. Unbonded concrete overlays are applied to deteriorated PCC pavements at Year 0.
2. The patching percentage for concrete pavements is based on the number of joints (jointed plain concrete).
3. For structural adequacy, the pavement overlay design life at Year 30 is 20 years. Pavement activities and structures must be determined by the engineer (e.g., thickness of AC base, intermediate and surface layers).
4. Functional mill and replace is a fixed activity at Year 40 in order to provide 10 additional years of life to the pavement surface and structure.
5. The full-depth patching percentage for composite pavements (after Year 30) is based on the number of underlying PCC joints (jointed plain concrete).
6. Milling to a depth of 2 inches is performed to remove the 1.5-inch wearing course and a portion of underlying layer to minimize scabbing.
7. Grinding of PCC surfaces is for improving ride quality.
8. PCC slab costs include the costs of tie bars, dowels, cut joints, and/or seal joints.

Pavement Activities Table

Year 0 – Rehabilitation (CPR and Unbonded Overlay)	**Year 10 – Concrete Pavement Maintenance**

Mainline (Pre-overlay Activities)
    Patching
    AC Bond Breaker/Separator Layer
AC Shoulders (if existing)
    Mill Existing AC if Deteriorated
    Patch Localized Failures
    AC Base Material
PCC Shoulders (if existing, pre-overlay activities)
    Patching
    AC Bond Breaker/Separator Layer
PCC Slab – Mainline and Shoulders
	Mainline
	    Patching – 3%
	    Clean and Seal Joint – 100%

Year 20 – CPR	**Year 30 – AC Overlay**
Mainline (Concrete Pavement Repair) Patching – 10% Clean and Seal Joints – 100% Grinding – 100%	Mainline Pre-overlay Repair: Patch – 10% AC Overlay (Minimum 4 Inches) with: AC Surface Material AC Intermediate Material AC Base Material Shoulders AC Overlay (Minimum 4 Inches) with: AC Wearing Course AC Intermediate Material AC Base Material

Year 40 – Structural Mill and Replace	**Year 50 – Salvage Value**
Mainline Pre-overlay Repair Patching (AC Overlay) Based on 5% of Underlying PCC Joints Patching (PCC Base) – 5% Mill - 2 Inches Replace with AC Intermediate Material – 2 Inches Overlay with AC Wearing Course – 1.5 Inches Shoulders Overlay with AC Wearing Course – 1.5 Inches	None

VIII. JOINTED CONCRETE PAVEMENT CONSTRUCTION/RECONSTRUCTION WITH TIED PORTLAND CEMENT CONCRETE SHOULDERS

For most projects, a jointed concrete pavement with tied PCC shoulders is a viable construction or reconstruction option. Jointed concrete pavement can be constructed on a new alignment or on an existing alignment. If the existing pavement on an alignment is flexible, then the jointed concrete pavement can be constructed on top of it (if geometrically feasible).

As with all pavement options, several criteria were established and assumptions made:

1. Initial pavement design life is 30 years.
2. Structural mill and replace is a fixed activity at Year 40 in order to provide 10 additional years of life to the pavement surface and structure. The 10-year period is the average life for an AC surface based on data in VDOT's pavement management database.
3. For structural adequacy, the pavement overlay design life at Year 30 is 20 years. Pavement activities and structures must be determined by the engineer (e.g., thickness of AC base, intermediate and surface layers).
4. The full-depth patching percentage for composite pavement is based on the number of underlying PCC joints.
5. The full-depth patching percentage for jointed concrete pavement is based on the number of transverse joints.
6. Milling to a depth of 2 Inches is performed to remove the 1.5-Inch wearing course and a portion of underlying layer to minimize scabbing.
7. PCC slab costs include the costs of tie bars, dowels, cut joints, and seal joints.

Pavement Activities Table

Year 0 - New Construction/Reconstruction	**Year 10 – Concrete Pavement Maintenance**

Mainline
    Pavement Removal (Reconstruction)
    PCC Slab
    Stabilized Drainage Layer
    CTA or DGA Subbase
Shoulders
    Shoulder Removal (Reconstruction)
    PCC Slab
    Stabilized Drainage Layer
    CTA or DGA Subbase
    Soil Stabilization
	Mainline
	    Patching – 3%
	    Clean and Seal Joint – 100%

Year 20 – Concrete Pavement Restoration	**Year 30 – AC Overlay**
Mainline (Concrete Pavement Repair) Patching – 10% Clean and Seal Joints – 100% Grinding – 100%	Mainline Pre-overlay Repair: Patch – 10% AC Overlay (Minimum 4 Inches) with: AC Surface Material AC Intermediate Material AC Base Material Shoulders AC Overlay (Minimum 4 Inches) with: AC Wearing Course AC Intermediate Material AC Base Material

Year 40 – Structural Mill and Replace	**Year 50 – Salvage Value**
Mainline Pre-overlay Repair Patching (AC Overlay) Based on 5% of Underlying PCC Joints Patching (PCC Base) – 5% Mill - 2 Inches Replace with AC Intermediate Material – 2 Inches Overlay with AC Wearing Course – 1.5 Inches Shoulders Overlay with AC Wearing Course – 1.5 Inches	None

IX. JOINTED PLAIN CONCRETE PAVEMENT CONSTRUCTION/RECONSTRUCTION WITH WIDE LANE AND ASPHALT CONCRETE SHOULDERS

For most projects, a jointed concrete pavement with wide lanes and AC shoulders is a viable construction or reconstruction option. Jointed concrete pavement can be constructed on a new alignment or an existing alignment. If the existing pavement on an alignment is flexible, then the jointed concrete pavement can be constructed on top of it (if geometrically feasible).

As with all pavement options, several criteria were established and assumptions made:

1. The initial pavement design life is 30 years for the mainline. For the AC shoulders, the total thickness of the AC layers will be equal to the thickness of the mainline PCC slab.
2. Structural mill and replace is a fixed activity at Year 40 in order to provide 10 additional years of life to the pavement surface and structure. The 10-year period is the average life for an AC surface based on data in VDOT's pavement management database.
3. For structural adequacy, the pavement overlay design life at Year 30 is 20 years. Pavement activities and structures must be determined by the engineer (e.g., thickness of AC base, intermediate and surface layers).
4. The full-depth patching percentage for composite pavement is based on the number of underlying PCC joints.
5. The full-depth patching percentage for jointed concrete pavement is based on the number of transverse joints.
6. Milling to a depth of 2 inches is performed to remove the 1.5-inch wearing course and a portion of underlying layer to minimize scabbing.
7. Grinding of PCC surfaces is for improving ride quality.
8. PCC slab costs include the costs of tie bars, dowels, cut joints, and seal joints.

Pavement Activities Table

Year 0 - New Construction/Reconstruction	**Year 10 – Concrete Pavement Maintenance**

Mainline with 14-Foot Lanes – Inside and Outside
    Mainline Removal (Reconstruction)
    PCC Slab
    Stabilized Drainage Layer
    CTA or DGA Subbase
Shoulders
    Shoulder Removal (Reconstruction)
    AC Surface Material
    AC Intermediate Material
	Mainline
	    Patching – 3%
	    Clean and Seal Joint – 100%
	Shoulders
	    Surface Treatment

Year 0 - New Construction/Reconstruction	**Year 10 – Concrete Pavement Maintenance**
AC Base Material CTA or DGA Subbase Soil Stabilization	

Year 20 – Concrete Pavement Restoration and Shoulder Improvement	**Year 30 – AC Overlay**
Mainline (Concrete Pavement Repair) Patching – 10% Clean and Seal Joints – 100% Grinding – 100% Shoulders Surface Treatment	Mainline Pre-overlay Repair: Patch – 10% AC Overlay (Minimum 4 Inches) with: AC Surface Material AC Intermediate Material AC Base Material Shoulders AC Overlay (Minimum 4 Inches) with: AC Wearing Course AC Intermediate Material AC Base Material

Year 40 – Functional Mill and Replace	**Year 50 – Salvage Value**
Mainline Pre-overlay Repair Patching (AC Overlay) Based on 5% of Underlying PCC Joints Patching (PCC Base) – 5% Mill - 2 Inches Replace with AC Intermediate Material – 2 Inches Overlay with AC Wearing Course – 1.5 Inches Shoulders Overlay with AC Wearing Course – 1.5 Inches	None

X. CONTINUOUSLY REINFORCED CONCRETE PAVEMENT CONSTRUCTION/RECONSTRUCTION WITH TIED PORTLAND CEMENT CONCRETE SHOULDERS

Continuously reinforced concrete pavement with tied PCC shoulders is a viable construction or reconstruction option. Continuously reinforced concrete pavement can be constructed on a new alignment or an existing alignment. If the existing pavement on an alignment is flexible, then the continuously reinforced concrete pavement can be constructed on top of it (if geometrically feasible).

As with all pavement options, several criteria were established and assumptions made:

1. The initial pavement design life is 30 years with a functional AC overlay at Year 20.
2. The pavement mill and replacement at Year 30 is fixed to provide 10 years of functional life. The 10-year period is the average life for an AC surface based on data in VDOT's pavement management database.
3. The complete removal and replacement of the AC overlay at Year 40 is a fixed activity in order to provide 10 additional years of life to the AC surface and pavement structure.
4. The full-depth patching percentage for composite pavement is based on pavement surface area.
5. The full-depth patching percentage for continuously reinforced concrete pavement is based on surface area.
6. Milling to a depth of 2 inches is performed to remove the 1.5-inch wearing course and a portion of underlying layer to minimize scabbing.

Pavement Activities Table

Year 0 - New Construction/Reconstruction	**Year 10 – Concrete Pavement Maintenance**
Mainline Mainline Removal (Reconstruction) PCC Slab Stabilized Drainage Layer CTA or DGA Subbase Shoulders Shoulder Removal (Reconstruction) PCC Slab Stabilized Drainage Layer CTA or DGA Subbase Soil Stabilization	Mainline Patching – 2% Clean and Seal Joint – 100%

Year 20 – Concrete Pavement Restoration and AC Overlay	**Year 30 – Functional Mill and Replace**
Mainline Concrete Pavement Restoration: Patching – 5% AC Overlay with: AC Wearing Course – 1.5 Inches AC Intermediate or Base Material – 2 Inches Shoulders AC Overlay with: AC Wearing Course – 1.5 Inches AC Intermediate or Base Material – 2 Inches	Mainline Patching (AC Overlay) - 5% Patching (PCC Base) – 5% Mill - 2 Inches Replace with AC Wearing Course – 2.0 Inches Shoulders Surface Treatment

Year 40 – Concrete Pavement Restoration and AC Overlay	**Year 50 – Salvage Value**
Mainline Concrete Pavement Restoration: Patch – 10% Mill - 3.5 Inches Replace with: AC Intermediate Material – 2.0 Inches AC Surface Material – 1.5 Inches Shoulders Surface Treatment	None

XI. CONTINUOUSLY REINFORCED CONCRETE PAVEMENT CONSTRUCTION/RECONSTRUCTION WITH WIDE LANES (14 FEET) AND AC SHOULDERS

Continuously reinforced concrete pavement with wide lanes and AC shoulders is a viable construction or reconstruction option. Continuously reinforced concrete pavement can be constructed on a new alignment or an existing alignment regardless of the existing pavement type. If the existing pavement on an alignment is flexible, then the continuously reinforced concrete pavement can be constructed on top of it (if geometrically feasible).

As with all pavement options, several criteria were established and assumptions made:

1. The initial pavement design life is 30 years with a functional AC overlay at Year 20. For the AC shoulders, the total thickness of the AC layers will be equal to the thickness of the mainline PCC slab.
2. The pavement mill and replacement at Year 30 is fixed to provide 10 years of functional life. The 10-year period is the average life for an AC surface based on data in VDOT's pavement management database.
3. The complete removal and replacement of the AC overlay at Year 40 is a fixed activity in order to provide 10 additional years of life to the AC surface and pavement structure.
4. The full-depth patching percentage for composite pavement is based on pavement surface area.
5. The full-depth patching percentage for continuously reinforced concrete pavement is based on surface area.
6. Milling to a depth of 2 inches is performed to remove the 1.5-inch wearing course and a portion of underlying layer to minimize scabbing.

Pavement Activities Table

Year 0 – New Construction/Reconstruction	**Year 10 – Concrete Pavement Maintenance**
Mainline with 14-Foot Lanes – Outside and Inside Pavement Removal (Reconstruction) PCC Slab Stabilized Drainage Layer CTA or DGA Base Shoulders Shoulder Removal (Reconstruction) AC Surface Material AC Intermediate Material	Mainline Patching – 2% Clean and Seal Joint – 100% Shoulders Surface Treatment

AC Base Material CTA or DGA Subbase Soil Stabilization	

Year 20 – Concrete Pavement Restoration and AC Overlay	**Year 30 – Functional Mill and Replace**
Mainline Concrete Pavement Restoration: Patching – 5% AC Overlay with: AC Wearing Course – 1.5 Inches AC Intermediate or Base Material – 2 Inches Shoulders AC Overlay with: AC Wearing Course – 1.5 Inches AC Intermediate or Base Material – 2 Inches	Mainline Patching (AC Overlay) – 5% Patching (PCC Base) – 5% Mill – 2 Inches Replace with AC Wearing Course – 2.0 Inches Shoulders Surface Treatment

Year 40 – Concrete Pavement Restoration and AC Overlay	**Year 50 – Salvage Value**
Mainline Concrete Pavement Restoration: Patch – 10% Mill – 3.5 Inches Replace with: AC Intermediate Material – 2.0 Inches AC Wearing Course – 1.5 Inches Shoulders Surface Treatment	None

XII. UNIT COSTS AND MEASURES

The life cycle cost for a pavement option is dependent on the corresponding activities required to construct and maintain the pavement. The cost for each activity is a function of unit cost and quantity measure. The following table provides units of measure. The measure is based on the Measurement and Payment Section in VDOT's *Road and Bridge Specifications* for each activity. The unit cost is based on historical and current costs to VDOT for similar or equivalent measures (i.e., quantities).

Activity	**Measure**
Milling/Planing	Square Yard – Inch
Fracturing PCC	Square Yard
AC Surface Material/Wearing Course	Tons
AC Intermediate Material	Tons
AC Base Material	Tons
Stabilized Drainage Layer	Tons
Pavement Demolition and Removal – Existing AC	Square Yard
Pavement Demolition and Removal – Existing PCC	Square Yard
Aggregate Subbase	Cubic Yard or Ton
Cement Treated Aggregate	Tons
Patching – CRCP	Square Yard
Patching – JPCP	Square Yard
Patching – AC	Tons
PCC Grinding	Square Yard
Joint Cleaning and Sealing	Linear Foot
CRCP	Square Yard
JPCP	Square Yard
Surface Treatment	Depends on Material Selected

XIII. INTERPERTATION OF RESULTS

Once the LCCA is completed for a project, the PW cost results must be interpreted. In general, the pavement option with the lowest PW cost should be strongly considered for the project. However, the PW cost for any pavement option is not exact; therefore, the engineer should consider all pavement options with a PW cost within 10% of the lowest PW cost as economically feasible. If more than one pavement option is determined to be economically feasible, then factors such as the following must be considered:

- initial constructability
- constructability of future improvements
- volume of traffic
- availability of materials
- availability of qualified contractors
- initial construction costs
- location of project.

Once the PW cost and other project factors are considered, then a pavement recommendation can be made.

APPENDIX A – LCCA SPREADSHEETS

APPENDIX B – EXAMPLE LCCA